

Conference Report

INFORMATION TECHNOLOGY FOR ENGINEERING AND MANUFACTURING Gaithersburg, MD June 12-13, 2000

Report prepared by

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1. Introduction

This paper summarizes material presented at the Information Technology for Engineering and Manufacturing conference. NIST's Systems Integration for Manufacturing Applications (SIMA) program office organized the conference to examine problems facing manufacturers as they incorporate the latest information technology applications in their operations, as well as current and future means of addressing those problems. The event was sponsored jointly by the SIMA program and NIST's Advanced Technology Program and took place on the main NIST campus in Gaithersburg, Maryland on June 12 and 13, 2000. James Fowler,

SIMA Program Manager, welcomed attendees and provided a brief overview of NIST and its mission. He highlighted the billions of dollars spent annually by U.S. companies to acquire, integrate, and troubleshoot manufacturing information technology applications. He maintained that standards-based solutions offer promising advantages in addressing problems of software integration and interoperability and presented three objectives for the conference:

- Identify impediments to software integration in key application areas.
- Identify standards, technologies, and tools addressing those impediments.
- Discuss gaps in the solutions and what could be done about those gaps.

The agenda consisted of three keynote speakers and a series of six sessions devoted to Product Data Management, Manufacturing Simulation, Knowledge-aided Engineering, Process Representation, e-Commerce for Manufacturing, and the eXtensible Markup Language. Sessions featured presentations by three to five speakers followed by a panel question-and-answer period.

2. Keynote Speakers

Gene Allen, Director of Collaborative Development at MSC Software, presented his views on the state of information technology (IT) in manufacturing, starting with examples of current, leading-edge implementations of IT across a range of industries. By expanding application of computer-aided engineering (CAE) and systems analysis to include even the conceptual and preliminary design processes, the overall robustness of a given design can be improved. As increasingly higher levels of interoperability emerge among CAE, computer-aided design (CAD), computer-aided manufacturing (CAM), and product data management (PDM)

systems, enterprises will be better able to manage a product over its entire life cycle and to interact with outside partners. Suppliers will routinely be as integrated into the process as if they were one of an enterprise's internal departments. Allen outlined a "Robust Design System" in which analysis information is incorporated dynamically into the product model. Probabilistic analysis can then provide significant gains over a conventional Test-Fail-Fix cycle in optimizing final design. He noted that the technologies necessary to exploit robust design routinely are available now, but that current business environments and cultures resist their integration. Allen envisioned a virtual enterprise in which improved product data interoperability would allow dispersed teams of companies and personnel, representing the best world-wide capabilities available at the time, to work together electronically at least as efficiently as a fully collocated team within one company. He then outlined keys to expanding the use of IT in order to reach the point where such a virtual enterprise would be feasible.

Richard Neal, Director of the Integrated Manufacturing Technology Initiative (IMTI), discussed IMTI and its goals and then elaborated on the Integrated Manufacturing Technology Roadmapping (IMTR) initiative. He defined IMTI as "an enabling organization dedicated to consensus, crosscutting, living plans and cooperative solutions for manufacturing success." IMTI has produced a series of roadmaps, documents which are detailed and evolving plans to enable industry and research organizations to proceed towards resolving challenges facing manufacturing enterprises. Neal noted that, even in its current state, information technology is revolutionizing how manufacturing enterprises operate. Using examples from the Roadmaps for Information Systems, Modeling and Simulation, and Enterprise Integration, he contrasted typical capabilities in these areas to the improved and interoperable capabilities necessary to manage and exploit knowledge efficiently and to integrate systems. In summary, he defined the IMTI visions for each area thusly:

Information Systems

- Real-time information systems that provide all of the right information, to the right place, at the right time, and in the right format.

Modeling and Simulation

- Digitally developed products and processes
- Processes controlled by real-time, integrated process models
- An enterprise-wide model-driven business and operations environment

Enterprise Integration

- Plug-and-play enterprises, totally connected in a plug-and-play environment, integrating business and operations functions for instant response across the supply chain.

Harris Liebergot, Acting Chief of the Information Technology and Applications Office (ITAO) of the NIST Advanced Technology Program (ATP), presented an overview of ATP and its mission. He highlighted the fact that ATP looks for projects that are pathbreaking or multi-use in nature, or which offer infrastructural support to industry. Scientific and technical merit and potential broad-based economic benefits receive equal weight when ATP reviews a proposal. A proposed project must present high risk, yet offer a sound path to eventual commercialization. Liebergot listed areas of specific interest to ITAO and then provided details of five projects ITAO has funded in the area of Intelligent Manufacturing. A review of the application process for ATP funding and a list of points of contact for various technical areas rounded out the presentation.

3. Product Data Management (PDM) Session

Simon Frechette, NIST Manufacturing Engineering Laboratory (MEL), Manufacturing Systems Integration Division (MSID), Manufacturing Standards Metrology Group Leader was the session chair.

Rick Bsharah, Senior Technical Specialist at Ford Motor Company, discussed Ford's approach to PDM implementation to optimize product development and its ultimate goal of a full electronic definition from product concept to manufacturing. He stressed the crucial role PDM plays in the ongoing transition to a process-driven environment but noted that current levels of industry data exchanges are relatively low. The Automotive Industry Action Group (AIAG) predicts significant growth of data exchanges. Bsharah noted the importance of buy-in and commitment by all participants in the product development process to foster continued evolution of the PDM environment.

Greg Saul, Chief Architect, PDM Products and Services, Boeing Commercial Airplanes Group (BCAG), centered his presentation on BCAG's experiences incorporating a process-planning interface. In detail, he explained how BCAG requirements are accommodated in the system's design and operation. Saul closed with a broad look at data management problems common across all of Boeing's enterprises.

Jim Kindrick, Senior Member of Technical Staff of Environmental Research Institute of Michigan (ERIM), spoke on the PDM Implementor Forum (PDM-IF) and

its work to specify and implement within the International Organization for Standardization (ISO) standard 10303 a core of entities that support PDM. (ISO standard 10303, Product data representation and exchange, is informally known as the Standard for Exchange of Product Model Data, or STEP.) He explained the test methods used to verify interoperability and conformance of applications performing STEP data exchanges and briefed the status of development and test campaigns conducted by PDM-IF members.

After the individual presentations, the panel responded to audience questions about the decision process Ford and Boeing each used in adopting an enterprise product data management system, the concomitant changes in their engineering processes, and the effects that decision had on the information technology architecture. Overall, the decision was based on the desire to improve the efficiency of their business processes, particularly with respect to the handling and propagation of engineering changes. The speakers emphasized that PDM implementation is an evolutionary process, that the state of implementation must be evaluated continually in terms of capabilities and benefits, and that the decision to adopt a PDM-centric strategy also affects each company's suppliers. The need for interoperability between a given PDM system and the other software systems with which it must interface, be they internal or at a supplier, is driving major manufacturers such as Boeing and Ford to participate in the development and deployment of information standards intended to address interoperability issues. However, there was recognition that in the absence of available standards, companies must pursue alternative strategies to address such interoperability issues.

4. Manufacturing Simulation (MS) Session

Session chair Charles McLean, NIST MEL, MSID, Manufacturing and Simulation Modeling Group Leader, presented an overview of MS efforts at NIST featuring demonstrations of several simulation scenarios. He discussed the Intelligent Manufacturing Systems Program's Modeling and Simulation Environments for Design, Planning and Operation of Globally Distributed Enterprises (MISSION) project and the potential advantages of distributed simulation.

Jerry Banks, Senior Simulation Technology Advisor at AutoSimulations, Inc. shared his views on the future of simulation. He believes that simulation is an indispensable, problem-solving methodology and that its use and impact in manufacturing will continue to

increase. Areas in which simulation technology improvements would be most beneficial include reducing complexity, increasing speed, improving optimization, and refining the High Level Architecture specification for interactions among simulation software systems.

Averill Law of Averill M. Law and Associates recommended techniques for conducting successful simulation studies. He highlighted the importance of soliciting input from knowledgeable people among the owners and operators of the system to be simulated, and involving them throughout the entire development, validation, and verification cycle. Application of proper probability distributions and careful analysis of simulation output statistics were other factors prominent in Law's observations.

The panel then responded to audience questions about the use of simulation systems and the problems of building simulations. It was noted that the complexity of simulation systems, the cost of such systems, and the substantial expertise that must be developed to create useful simulations are all barriers to the widespread use of simulation technology. It was noted that neutral models of manufacturing equipment for simulation purposes would reduce the time needed to build complex simulations of manufacturing enterprises. Discussion of the problems in building useful simulations focused on the issue of lack of data, i.e., what to do when data characterizing a particular manufacturing process that is to be part of the overall simulation is insufficient. In such cases, approximations are used with the caveat that the simulation developer needs to be aware of the limitations resulting from such approximations and their impact on the overall simulation model.

5. Knowledge-Aided Engineering (KAE) Session

Ram Sriram, NIST MEL, MSID, Design and Process Group Leader, was the session chair.

Vijay Srinivasan, Engineering Consultant, Corporate CAD/CAM Group, IBM Corporation and Adjunct Professor, Fu Foundation School of Engineering and Applied Sciences, Columbia University, contrasted the differences between data, information, and knowledge and explained the roles that correlation, causality, and sensitivity play in engineering knowledge. Direct modeling of knowledge is still beyond our grasp, but we can improve our capabilities to capture elements of engineering knowledge in conventional forms such as prose, equations, and graphics and to make these elements available to engineers using current and emerging technologies.

Richard Zarda, Manager of the Engineering Methods Group at Lockheed-Martin Missiles and Fire Control, provided an overview of Lockheed's Interactive Missile Design Environment (IMDE). This web-based system is based on the Advanced Modeling Language and incorporates Lockheed's Interactive Gimbal Design and Interactive Missile Design systems to capture and organize engineering data and to enable full integration of engineering tools. IMDE allows multiple users to simultaneously work with a common model in real-time collaborative sessions.

Simon Szykman, a mechanical engineer of the NIST MEL, MSID, Design and Process Group, highlighted NIST efforts to define an Intelligent and Distributed Engineering Design (IDED) product development system incorporating representations of knowledge much more complete than those available today. These representations would be generic and non-proprietary, facilitating future standards development, and would likely reduce interoperability costs and product development times and increase knowledge retention and reuse. Szykman briefly demonstrated a design repository, showing how an artifact could be decomposed in form, function, and behavior.

The panel addressed questions about the requirements to implement KAE in practice. The Lockheed speaker discussed the labor investment expended to implement KAE for missile design and the complexity of capturing knowledge for complex engineering designs. There was also discussion about the capabilities engineers would like to see in KAE systems and the difficulties of adding such capabilities. Finally, there was acknowledgement of the need to maintain multiple representations of the same engineering knowledge and of the difficulties associated with maintaining those representations of engineering knowledge over time.

6. Process Representation Session

Michael Gruninger, a guest researcher in the NIST Manufacturing Engineering Laboratory, MSID, was the session chair.

Paul Wu, Senior Consultant at Lucent Technologies—Bell Labs, explained how Lucent's Network Solutions group is expanding its risk-management analyses to cover the pre-sales bidding and contracting and post-sales implementation phases of network projects. Application of such a disciplined risk-management strategy across an entire project improves the chances that a successful long-term solution acceptable to both the customer and to Lucent will emerge. Identification of risk facilitates mitigation, which in turn reduces financial exposure.

Benjamin Perakath, Vice President of Research and Development at Knowledge Based Systems, Inc., gave a version of a presentation originally prepared by Frank Boystun of the Air Force Oklahoma City Air Logistics Center (ALC) and who was unable to attend the conference. The ALC has attempted to continually improve acquisition, understanding, and management of knowledge about its varied processes in order to more efficiently meet the often-unpredictable demands of aircraft depot maintenance. Gains in process knowledge have benefited analysis, quality, planning and scheduling, training, IT support, and day-to-day management of processes.

Gruninger spoke on the Process Specification Language (PSL), a semantics-based language intended to facilitate the exchange of process information among manufacturing systems. He briefly covered the semantic mapping process and provided details of work to date, project collaborators, and expected future development. ISO has accepted PSL as a preliminary work item.

Audience members asked about the means of encoding PSL in the eXtensible Markup Language (XML) and whether there is a need to extend XML for that purpose. There was discussion about the possibility of using PSL to support run-time execution of processes in addition to its capabilities for exchange of static process information. The panel agreed that PSL could be extended for run-time purposes though that was not the planned direction for PSL development. The audience also sought clarification about how existing process-based software systems could be adapted to work with PSL to achieve interoperability; the panel described the process of mapping information representations into and out of PSL. There were also brief discussions of the ability of PSL to handle non-deterministic processes, how it could be used to help enable virtual enterprises, integrating PSL with product representations, and the relationship of PSL to existing programming languages.

7. e-Commerce for Manufacturing Session

Barbara Goldstein and James St.Pierre, both NIST employees on assignment to the Commerce Department's Technology Administration, co-chaired the session.

John Teets of the Silicon Integration Initiative discussed the standard for Electronic Component Information Exchange (ECIX) and QuickData, an XML-based exchange protocol that enables rapid access to detailed component physical and performance characteristics, as well as pricing, delivery, and life-cycle information. Teets also covered activities intended to align ECIX work with other, related standardization efforts.

St.Pierre elaborated on the rationale behind NIST efforts to develop standards and reference software applicable to electronic commerce of component information and John Messina provided a live demonstration of NIST's QuickData implementation.

Chuck Richardson, Corporate Engineering Manager at SCI Systems, talked about the difficulties posed by the variety of CAD data and data transfer formats used by SCI's customers. He contrasted today's typical methods of data transfer with an approach that would be possible if CAD data provided by original equipment manufacturers to suppliers were in a standardized format.

Goldstein spoke on the NIST Internet Commerce for Manufacturing (ICM) project and its work to develop a suite of web-based standards to assist the electronics manufacturing supply chain to meet ever-tighter time-to-market demands in the face of increasing outsourcing. She showed examples of web-based manufacturability analyses, an engineering change order, and a conformance test module, each developed by the ICM project.

Mangesh Bhandarkar of Netfish Technologies described the Virtual Factory Prototype project, an effort to define and address information interchange issues within the increasingly dispersed electronics manufacturing industry.

The panel responded to audience questions about extensions to the reference implementation of QuickData as described and demonstrated during St.Pierre's presentation. Particular interest was expressed as to whether the results presented in a search for a component supplier could be ranked according to price, availability, or other criteria. The panel responded that such rankings could be generated if the QuickData format were extended to provide such information and that the reference implementation demonstrated was intended as a proof-of-concept rather than as a software system that would support production usage. In addition, the panel emphasized that the attraction of the initial QuickData format is its low cost of adoption and that a phased approach of extending the format with additional component characteristics is being pursued. The audience also sought clarification of how the work described in the presentations regarding the QuickData format and RosettaNet specifications related to recently announced electronics industry online trading exchanges. The panel pointed out that the interoperability specifications being promulgated through RosettaNet and the Silicone Integration Initiative (Si2) would likely have a role to play in those trading exchanges. Finally the panel fielded questions regarding the relationship of STEP to the specifications discussed as well as that of the Product Definition Exchange (PDX) specification.

8. XML for Manufacturing Systems Integration Session

Session chair Thomas Rhodes, a computer specialist in the NIST Information Technology Laboratory, Software Diagnostics and Conformance Testing Division, Standards and Conformance Testing Group, spoke on XML for manufacturing systems integration. After an overview of XML itself, he reviewed NIST XML projects related to manufacturing, devoting particular attention to the PSL and STEP Modularization initiatives. Rhodes then covered XML architectural forms and the Extensible Style Language for Transformations (XSLT), two XML technologies that can be used to map languages between applications.

David Briggs, Associate Technical Fellow, Information Services Division, BCAG, discussed the use of XML in conjunction with STEP-exchanged product data to address design collaboration and supply chain integration issues. This combination makes web-based design exchange practical, with resultant gains in overall data manageability, speed, cost, and access.

Martin Hardwick, President of STEP Tools, described the use of XML Document Type Definitions to add or extract subsets of data to or from a shared STEP database. This allows modification of specific features, procedures, or administrative data without transfer and multiple retranslations of an entire STEP file, and can reduce or eliminate reliance on paper drawings.

Johannes Soons of the NIST MEL, Automated Production Technology Division, Manufacturing Laboratory Sensor Systems Group spoke on the use of a standardized representation of machine tool performance data to facilitate its efficient archiving and exchange. Ready access to details of configuration and capabilities of various machine tool models as well as machine-specific performance test data would help to ensure that the most appropriate machines and cutting tools are used to produce a part.

The audience inquired about the advantages of using XML to encode complex content such as that found in the STEP standards. Among the advantages cited by the panel are the number of software tools available for working with XML-encoded data and the ease of interpreting XML-encoded data. It was pointed out that XML encoding results in larger data files than those containing data in the existing STEP exchange format. Still in the discussion of the relative merits of using XML to encode STEP content versus the existing STEP exchange mechanisms, it was noted that the use of XML provides capabilities for fine-grain access to data elements. The panel also pointed out that XML is not in and of itself a panacea, in that it does not help resolve the complex issues arising in the definition of content

specifications. Noting that XML is easy to read, the point was raised that wider use of XML for exchange would possibly help specification developers harmonize overlapping specifications. Finally, the panel fielded questions related to the relevancy of formal standards developing organizations in light of establishment of web-based XML specification repositories, and the relationship of the standards discussed to the Scalable Vector Graphics specification.

9. Presentations

Full conference presentations are available in the “Events” section of the SIMA web site (www.nist.gov/sima).